UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

Sent via email only

August 19, 2020

Rebecca Hollis
Clean Energy Systems
3035 Prospect Park Dr., Suite 120
Rancho Cordova, California 95670

Re: Technical Evaluation Comments and Information Request for
Underground Injection Control (UIC) Permit Application
Class VI Pre-Construction Permit Application No. R9UIC-CA6-FY20-1

Dear Ms. Hollis:

The United States Environmental Protection Agency, Region 9 (EPA) has conducted a technical evaluation of the geologic site characterization information provided in the Narrative of the subject permit application. Based on this evaluation, we have identified additional information or clarification needed for EPA's continued evaluation of the permit application. We also identified several uncertainties that CES will be required to address with pre-operational testing at the Mendota site.

Considerations of Specific Federal Laws

40 CFR §144.4 requires that EPA consider the potential applicability of several specific Federal Laws, including the Wild and Scenic Rivers Act (WSRA), National Historic Preservation Act (NHPA), Endangered Species Act (ESA), Coastal Zone Management Act (CZMA), and the Fish and Wildlife Conservation Act (FWCA). To expedite our consideration of these laws, please describe how the proposed project will satisfy applicable requirements under those Federal Laws. For the ESA and NHPA, we have included some guidance below to assist you with obtaining the required information.

Endangered Species Act (ESA)
The ESA requires EPA to ensure, in consultation with the U.S. Fish and Wildlife Services (FWS), that any action authorized by EPA is not likely to jeopardize the continued existence of any endangered or threatened species or adversely affect its critical habitat. We recommend that you use FWS's project planning tool to map out your project area and do a search for potential endangered species within your project area. The tool can be accessed here: https://ecos.fws.gov/ipac/.

Based on the results of your search, you may need to hire a Wildlife Consultant to provide additional analysis or otherwise show how your project will not cause harm to endangered species with habitat located near the Mendota site. Please provide a report depicting the results of the FWS project planning tool, including a map of the project area and any listed endangered or threatened species habitat near the site. Please include any comments or reports made by a Wildlife Consultant, if applicable.

National Historic Preservation Act (NHPA)
NHPA §106 requires a federal agency to take certain steps before it commits to any "undertaking," including the issuance of a permit or license, that has the potential to adversely affect property that is listed, or eligible for listing, in the National Register for Historic Places. The NHPA requires EPA, before issuing a permit, to adopt measures when feasible to mitigate potential adverse effects of the permitted activity and properties listed or eligible for listing in the National Register of Historic Places. The Act's requirements are to be implemented in cooperation with State Historic Preservation Officers and upon notice to, and when appropriate, in consultation with the Advisory Council on Historic Preservation.

For CES to obtain NHPA clearance, we recommend that you identify the Historic Places designated in the National Register for Historic Places (https://www.nps.gov/subjects/nationalregister/database-research.htm) in close proximity to the Mendota site. Based on the results of your review of the National Register of Historic Places listings in Fresno County, you may need to hire an archaeologist to provide additional analysis or otherwise show how your project will not adversely affect the identified historic places located near the Mendota site. Please provide a list of the Historic Places near the site. Please include any comments or reports made by an archaeologist, if applicable.

Please submit the requested information in the Enclosure and regarding compliance with the above referenced Federal Laws by September 30, 2020. If you have any questions about this letter and the Enclosure, please contact me at (415) 972-3971 or call Calvin Ho at (415) 972-3262.

Sincerely,

DAVID ALBRIGHT
Digitally signed by DAVID ALBRIGHT
Date: 2020.08.19 10:58:36 -07'00'

David Albright
Manager, Groundwater Protection Section

Enclosure

cc (via email): Chris Jones, CalGEM Inland District
Clay Rodgers, Central Valley Regional Water Quality Control Board
John Borkovich, CA State Water Resources Control Board
Amit Garg, CalGEM

ENCLOSURE

Site Characterization Evaluation of the CES-Mendota Class VI Permit Application

This site characterization evaluation report for the proposed CES-Mendota geologic sequestration project summarizes the geologic evaluation and data submitted by CES in the Class VI UIC permit application narrative per 40 CFR 146.82(a) and 146.83. It describes and evaluates the available data on which the permit application for Well Mendota_INJ_1 (the proposed injection well) is based and identifies uncertainties that CES will be required to address with pre-operational testing at the Mendota site before CES will receive an authorization to inject CO_2. This evaluation also identifies additional information or clarification needed for EPA's continued evaluation of the permit application.

Regional Geology and Geologic Structure

The Mendota site is located in the central San Joaquin Basin, situated along the basin's deepest axis. The basin contains 25,000 feet of sediment, spanning various changes in sea levels and tectonic settings. The San Joaquin Basin trends NW-SE and is aligned with the Sierra Nevada at its eastern edge. The proposed injection zone, the Cretaceous age First and Second Panoche Sands of the Panoche Formation, and confining layer, the Moreno Shale, pinch out against the Sierra Nevada basement rocks to the east. In addition to the Moreno Shale, laterally heterogenous turbidite deposits form interbedded shales that act as stratigraphic traps within the Panoche Formation (page 15). The central San Joaquin Basin is shown in depositional model in Figure 3 and cross section in Figure 4 (page 16) and stratigraphic column in Figure 5 (page 17). In this part of the basin, the subsurface dip is approximately 4 degrees to the SW (page 18). CES delineated a pressure-based area of review (AoR) that extends over a 2.2 square miles surface area to the northeast of the proposed injection well (it is all within a 2-mile radius to the northeast).

The permit application is based on log data from 10 wells to the north, east, and south of the proposed injection well. Resistivity logs were run in all 10 wells; most also have spontaneous potential (SP) or compressional slowness (from acoustical logs) or both; 3 have gamma ray, bulk density, and neutron porosity logs. Core samples are available from 1 well (NAPA AVE A/1, about 3 mi to the east). While there are no well data to the west of the proposed injection well, CES acquired 2D seismic data for areas to the west.

Faults and Fractures

To evaluate the faults and fractures in the region and in the AoR, CES gathered faulting data from public sources and interpreted them locally across three 2D seismic lines (Figures 16-18). These seismic lines are shown in three dimensions in Figure 19 (page 31). Most of the faults in the area are small throw features, with a few exceptions. Faults 1 and 2 trend north and separate the Mendota AoR from the Gill Ranch Field to the east. These are shown in the seismic line in Figure 16. The location of Fault 1 is indistinct, and more information is needed for accurate positioning (page 26). Faults 3 and 4 are located nearer to the proposed injection well and have small normal displacement, but do not appear to extend above the Third Panoche Formation. Fault 13 dips approximately 30 degrees SE and passes below the Mendota_INJ_1 well injection target at a depth of 9,850 TVDSS. The exact nature of this feature is unknown, but because its dip orientation is perpendicular to the regional principal stress direction of ~N45E, CES interprets the fault as strike-slip or due to wrenching or differential settlement in the basin (page 26).

A fault seal analysis was conducted on Fault 13 using a geocellular model. Based on this analysis, CES concluded that sediment displacement across the fault is likely low, and that injected fluid will therefore be confined to the Second Panoche Sands injection zone. If sediment displacement is high, injected fluids may migrate but would be limited to zones below the Moreno Shale because the clay from the Moreno would smear along the fault during displacement (pages 26-27). The clay content, based on Fault Clay Prediction, is shown in Figure 22 (page 33). At this time, no hydrocarbons have been identified in exploration wells to determine whether the fault is sealing. Furthermore, CO_2 plume simulations show the plume migrating to the northeast, away from Fault 13 (page 27).

Questions/Requests for CES:

- *What are the blue lines that trend NW-SE in Figure 14? Do these represent faults, and if so, which ones?*
- *The text on Figures 16-19 is difficult to read. In particular, it is not possible to identify Faults 1, 2, 3, 4, and 13 on Figure 19. Are higher resolution figures available?*
- *On page 15, the application states that there are two known faults near the Mendota site. To which two faults does this refer?*
- *What is the extent of the planned 3D seismic survey?*

Objectives for Pre-Operational Testing:

- *Determine the position of Fault 1 via 3D seismic data.*
- *Determine the nature of the displacement of Fault 13.*
- *Collect core data to demonstrate the sealing capacity of Fault 13.*
- *Perform 3D geomechanical modeling based on data collected via well logs, geomechanical core analysis, and well testing, combined with 3D seismic data to better characterize the faults in the area and determine their sealing capacity and that they are non-transmissive.*

Depth, Areal Extent, and Thickness of the Injection and Confining Zones

The Panoche Formation is regionally located at 8,000-12,000 feet below ground surface (bgs). Based on the stratigraphic column (Figure 5), the Second Panoche Sands (the primary injection zone) is approximately 8,900-10,000 ft bgs. A second, potential injection zone is the Fourth Panoche, located from about 10,900-12,500 ft bgs. These intervals are also shown on the cross section in Figure 6. Section 2.2 of the application narrative states that the proposed injection targets are the First and Second Panoche Sands, whose tops are estimated at depths of 8,437 and 8,918 ft bgs, respectively. Formation surface maps (Figure 12) and isochore maps (Figure 13) show that all units are laterally continuous across the region. According to the isochore maps in Figure 13, the First Panoche ranges in thickness from about 275 to 750 ft across the 5-mile radius from the Mendota site, the Second Panoche ranges from 780 to 1,170 ft, and the Fourth Panoche ranges from 1,400 to 2,500 ft.

The primary confining layer is the Moreno Shale, which is regionally located directly above the Panoche Formation at 7,000-8,000 ft bgs. On the stratigraphic column in Figure 5, the Moreno Shale is located at 7,350-8,450 ft bgs (page 17). According to the isochore map in Figure 13, the Moreno Shale ranges in thickness from about 500 to 1,650 ft across the 5-mile radius from the Mendota site.

Secondary stratigraphic seals are provided by shales within the Panoche Formation. According to Figure 5, the First Panoche Shale is from 8,800-9,000 ft bgs, and the Third Panoche Shale is from 10,300-10,900 ft bgs. According to the isochore maps in Figure 13 (page 25), the First Panoche Shale ranges in thickness from about 60 to 190 ft across the 5-mile radius from the Mendota site, and the Third Panoche Shale ranges from about 200 to 1,100 ft.

The north-south trending cross sections are corroborated by the 2D seismic data, in terms of dip and approximate formation depths. The images based on seismic data do not show the separate shale layers within the Panoche Formation, whereas the cross-section does. This will be confirmed via pre-operational testing and the planned 3D seismic survey.

The table below summarizes the depth and thickness of the formations of interest.

Unit	Depth	Approximate thickness across AoR (Figure 13 isochore maps)
Moreno Shale	7,332 ft bgs (Narrative pg 18)	500-1,650 ft
First Panoche	8,437 ft bgs (Narrative pg 18)	275-750 ft
First Panoche Shale	8,800 ft bgs (Figure 5)	60-190 ft
Second Panoche	8,918 ft bgs (Narrative pg 18)	780-1,170 ft
Third Panoche	9,950 ft bgs (Figure 5)	150-750 ft
Third Panoche Shale	10,300 ft bgs (Figure 5)	200-1,100 ft
Fourth Panoche	10,900 ft bgs (Figure 5)	1,400-2,500 ft

Objectives for Pre-Operational Testing:

- *Confirm thicknesses and depths of the injection and confining zones at the Mendota site through seismic imaging and information gained during drilling of the proposed injection well and deep monitoring well.*

Hydrologic and Hydrogeologic Information

The lowermost underground source of drinking water (USDW) is an unnamed interval within the Santa Margarita Formation that is estimated to be present around 1,600 ft bgs (page 18), or 1,415 ft TVDSS (page 57); this is located 7,165 feet above the top of the Second Panoche Sands (page 59). The total dissolved solids (TDS) content was determined by applying Archie's equation to the resistivity logs of 5 wells to the north and south of the Mendota site to determine TDS values. CES states that calculated salinity indicates that the base of the USDW is between 1,200 to 1,450 feet TVDSS. Uncertainties in this estimate include formation porosity, Archie equation parameters (standard parameters were used for now), and the effects of clay (page 57).

According to field data sheets for wells located in nearby oil and gas fields, the Jergins Formation at Cheney Ranch and the Blewett Formation at Merril Ave have salinities of 8,500 and 15,000 mg/L, respectively. The Jergins and Blewett Formations are in the Moreno Shale. Salinities of these sands at the Mendota site will need to be confirmed via sampling and analysis during drilling of the characterization well.

CES retrieved shallow groundwater well information from the California Department of Water Resources. There are 525 active and non-active water wells within a 5mile radius of Mendota_INJ_1, in all directions from the proposed site. Accurate locations of these wells are not known at this time. The wells range in depth from 50 to 500 feet. Their water levels, which were recorded at the time of drilling, were used to estimate groundwater elevation and flow direction. At the Mendota site, the shallowest groundwater is around 32 feet bgs (114 ft TVDSS). The San Joaquin River flows north south and is 0.6 miles east of the site. For the AoR and Corrective Action Plan in Attachment B, CES used a fixed well search radius of 2.5 miles in order to account for uncertainty in the model, and so the water well summary in that document does not agree with the application narrative (Section 5.1.1 of Attachment B).

Questions/Requests for CES:

- *The application states that the base of the lowermost USDW is estimated between 1,200 to 1,450 feet TVDSS, while the depth to the USDW is estimated at 1,415 TVDSS. Please clarify the discrepancy.*
- *Please provide a legend or labeled contours for the potentiometric map in Figure 47.*
- *What is the vertical distance between the First Panoche Sands and the lowermost USDW?*
- *Figure 46 includes a line marking the base of fresh water at 10,000 TDS. Section 2.7.1 of the application narrative discusses a BFW of 3,000 mg/L. Please confirm that no evaluations of the lowermost USDW are based on a definition of 3,000 mg/L.*
- *Figure 45 also appears to demarcate the BFW and the USDW based on salinity, but the resolution of the figure is too low to read the legend. Please provide a higher resolution version of Figure 45.*

Objectives for Pre-Operational Testing:

- *Sample formation water collected during drilling of the injection and monitoring wells to determine the base of the lowermost USDW and confirm that available resistivity logs and data from nearby fields is representative of the Mendota site.*
- *Verify the salinities for the permeable Jergins and Blewett formations within the Moreno Shale at the Mendota site to confirm that none are USDWs.*

Geochemistry

Characteristics of Injection Zone Formation Water

There was no available formation water information in the Panoche Formation at the Mendota site. Available formation water information from nearby oil and gas fields shows that TDS is 20,900 mg/L in the Panoche Formation at Gill Ranch, and 14,000 mg/L in the Moreno Shale at Cheney Ranch (Table 6).

There appears to be only one data point in the table for the Panoche Formation, at Gill Ranch, which is approximately 6.5 miles to the northeast of Mendota. The table does not indicate which Panoche Sand the value represents, and the depth is shallower than the target formation at the Mendota site. The text states, however, that there are wells at Gill Ranch that penetrate through the Fourth Panoche Sand. CES anticipates a salinity of about 25,000 mg/L at the Mendota site, although it is not stated what this is based on other than possibly a general increase in salinity moving westward.

CES states that logs from wells in the AoR do not indicate that any sand unit has formation water fresher than the Panoche Formation and acknowledges that this is an area of uncertainty. CES also states that formation water sampling for the Panoche Formation and overlying sands is included in the proposed testing plan in Attachment G. The plan indicates fluid testing for geochemistry in both the proposed injection well and observation well. Table 10 of the Testing and Monitoring Plan identifies analytical and field parameters for fluid sampling in the injection zone. It includes TDS along with a suite of other parameters.

Questions/Requests for CES:

- *Were any of the data values in Table 6 based on fluid sampling or well logs? If so, how many data points do the values represent?*
- *The data point from Gill Ranch is 6.5 miles away and represents a depth shallower than the Mendota injection zone. Cheney Ranch is approximately 12 miles southwest of the Mendota site. Please provide information to demonstrate the degree to which data from these fields are representative of the Mendota site.*

Objectives for Pre-Operational Testing:

- *Confirm the TDS values in the sand units within the Panoche Formation and in the Moreno Shale.*
- *Obtain a complete water analysis in the injection zone to provide inputs to support the geochemical modeling and determine whether available data from nearby fields is representative of the Mendota site. The analytical parameters should match/provide a baseline for future testing and monitoring.*

Mineral Composition of The Injection Zone

Mineralogic information for the injection zone comes from the Fourth Panoche Sand at the B.B. Co 1 well, which is in the AoR (within 2.5 miles northeast of the proposed injection well). The estimated mineral composition for the Panoche Formation described in Table 7 is proposed for geochemical modeling. However, Table 7 does not specify which Panoche sand layers the data represents. Data specific to the targeted injection zone (i.e., the First and Second Panoche Sands) at the Mendota site will be needed.

Table 7: Estimated mineral composition (wt. %) for the Panoche Formation used in geochemical modeling

Quartz	K-feldspar	Plagioclase	Calcite	Pyrite	Muscovite	Chlorite	Illite	Kaolinite
60	10	15	4.5	0.5	2	2	6	Trace

The testing plan in Attachment G describes planned core analysis by x-ray diffraction for core samples in both the proposed injection well and deep monitoring well.

Questions/Requests for CES:

- *How many core samples are proposed to be analyzed and from what depths?*
- *Does CES propose to perform other analyses of core samples besides XRD to document the mineralogy of the injection zone (e.g., polarized light microscopy)?*

Objectives for Pre-Operational Testing:

- *Obtain a mineralogic analysis of the injection zone and confining zone solids that represents the Mendota site.*

Geomechanical and Petrophysical Characterization

Petrophysical properties of the injection and confining zones were estimated using the well log data from 10 wells to the north, east, and south (primarily to the east) of the proposed injection well drilled between 1942 and 1987 (Table 2); the data were analyzed using Techlog software. Only two of the wells listed in Table 2 are within the 5-mile radius as shown in Figure 8--these are B.B. Company /1 (2.32 miles to the northeast) and Sterling-Coleman/1 (about 4 miles to the southeast).

The well log data were upscaled and used as the basis for populating properties throughout a geomodel, which ultimately supports numerical modeling of the Mendota site.

On page 34, CES states that "The petrophysical workflow involved building a model using well log data from NAPA AVE A/1 calibrated to core data for the same well (TGS, 2019)." The NAPA AVE A/1 well is 3 miles east of the site.

Questions/Requests for CES:

- *Given that the available porosity and permeability values are based on logs from 10 wells of different ages and spread over several miles, what information is available to demonstrate that these are comparable and representative of the Panoche Formation within the AoR?*
- *What method(s) was/were used to calibrate the well log data to the core data?*
    - *What is the error/variability associated with these methods?*
    - *Will the same method(s) be used to calibrate the core data to the well log data at the Mendota site?*
- *What is the spatial resolution of the log measurements?*

Objectives for Pre-Operational Testing:

- *Gather site-specific measurements during drilling of the proposed injection well and deep monitoring well of capillary pressure, and information on fractures, stress, ductility, rock strength, elastic properties, and in situ fluid pressures within the confining zone to support an evaluation of confining zone integrity.*

Porosity

The average Panoche Formation porosity estimates range from 20% in the First Panoche Sand to 10% in the Fourth Panoche Sand (Table 3). Average estimated porosity in the primary injection zone, the Second Panoche Sand, is 18% (page 39). The Moreno Shale is estimated to have an average porosity of 8%.

Total porosity of the injection zone was determined from bulk density or compressional slowness (run in 5 wells to the east and southeast of the proposed injection well). The clay volume (VCL), estimated from spontaneous potential or gamma ray logs (run in 10 wells), and irreducible water were then used to estimate effective porosity; the water associated with clay minerals and irreducible water must be removed from the total porosity to estimate effective porosity. CES acknowledges that there is uncertainty in the estimated effective porosity because an empirical relationship was used to estimate irreducible water.

Questions/Requests for CES:

- *What is the empirical relationship that was used to estimate irreducible water? How much uncertainty does this relationship entail?*
- *For the VCL estimates, Table 4: (Mineralogy summary from core XRD – NAPA AVE A 1; page 39) shows 10-22% potassium feldspar in the samples. Will that percentage of alkali feldspar bias the VCL values from gamma ray logs? Also, what units/depth/ were used as the reference points for clean sand and shale for the VCL estimates?*
- *The application narrative states, on page 34, that VCL log values greater than 30% were considered to be shale and anything less than 30% VCL was flagged as sand. What is the basis for this interpretation?*
- *How many analyses for porosity are proposed to be performed with cores from drilling of the proposed injection well and observation well?*

Objectives for Pre-Operational Testing:

- *Obtain laboratory core data on porosity at the Mendota site for the injection and confining zones to confirm the representativeness of the available data from nearby oil fields, support calibration to well logging data, and support development of the porosity distribution in the geomodel.*
- *Obtain core and well log data that will help identify vertical heterogeneity in porosity.*
- *Obtain well logging data to support log-based porosity calculations and calibration to core analyses.*
- *Verify estimates of irreducible water that were presented in the permit application.*

Permeability

The Panoche Formation permeability estimates range from 300 mD in the First Panoche Sand to 87 mD in the Fourth Panoche Sand (Table 3). Estimated average permeability in the primary injection zone, the Second Panoche Sand, is 290 mD (page 39). The Moreno Shale is estimated to have an average permeability of 4.7 mD (page 39).

Page 38 of the application states that: "The intrinsic permeability was estimated based on the porosity and lithology of the formation (Herron, 1987) using the wells around Mendota_INJ_1 (Figure 29). The lithology model consisted primarily of Quartz, Clay and Feldspars based on the core from NAPA AVE A/1. The relationship of porosity vs permeability is show in Figure 30. The average permeability of both the injection and confining zones is shown in Table 3 and Figure 31 shows the spatial variations in permeability thickness (KH) for the different formations."

Questions/Requests for CES:

- *How many analyses for permeability are proposed to be performed with cores from drilling of the proposed injection well and observation well?*
- *The text mentions "facies logs" (e.g., on page 40). Does this refer to the VCL data derived from the well logs?*

Objectives for Pre-Operational Testing:

- *Obtain laboratory core data on permeability at the Mendota site for the injection and confining zones to confirm the representativeness of the available data from nearby oil fields, support calibration to well logging data, and support development of the permeability distribution in the geomodel.*
- *Obtain well logging data to support log-based permeability calculations and calibration to core analyses.*
- *Obtain core and well log data that will help identify vertical heterogeneity in permeability.*

Mineralogy, Petrology, and Lithology of the Injection and Confining Zones

The Panoche Formation consists of layers of deep marine shale and submarine fan deposit intervals (page 15). Although the target injection zones are the First and Second Panoche Sands at the proposed injection site, CES bases their description on a core sample from the Fourth Panoche Sand (Depth: 11,422 – 11,471 ft) taken at the B.B. Co Well 1 located 2.32 miles from the storage site. (page 64; Attachment B, page 20). The Panoche Sands contain a mixture of sandstone and conglomerate. The sandstone contains mostly coarse, poorly sorted quartz and feldspar grains, cemented by calcite. There is also an abundance of biotite with low amounts of chlorite, muscovite, and pyrite (page 64). This analysis is consistent with a sample taken from NAPA AVE A/1 located 9 miles from the site at depths between 8,200-8,751 ft, roughly correlating with the depth of the proposed injection zone (page 34).

Table 4 shows that the lithology of the NAPA AVE A/1 sample, obtained through core X-Ray Diffraction (XRD) consists primarily of quartz, clay, and feldspars (page 39). Uncertainties include lateral conformity to the site, leading to potentially different minerology and reservoir properties. CES plans to sample a core at a characterization well (page 27). CES has done initial geochemical modeling to address the potential for mineral precipitation and dissolution, with possible changes in porosity and permeability. Future cores should include samples from the confining layers, with measurements of mineral composition.

Questions/Requests for CES:

- *The NAPA AVE A/1 sample is taken at a depth that correlates to the injection zone. On page 18, it is noted that the sand and shale facies vary in lateral extent and thickness. Is there additional evidence indicating that the injection zone sample taken from NAPA AVE A/1 is analogous to the site injection zone?*

Objectives for Pre-Operational Testing:

- *Obtain core samples during drilling of the proposed injection well and deep monitoring well to characterize the mineralogy and lithologies of the injection and confining zones at the Mendota site.*

Seismic History and Seismic Risk

The Mendota site is located near the center of the San Joaquin Basin, which is less tectonically active than the margins of the basin. Historical earthquake data were obtained from the USGS Earthquake Hazards database. All earthquakes in the region since 1900 with a magnitude greater than 2.5 were taken into account. Major fault systems in the region include the San Andreas Fault approximately 40 miles to the southwest and the San Joaquin and Ortigalita fault systems approximately 15 to 20 miles to the south and west. The nearest cluster of quakes, all less than 5.0 magnitude, occur along the San Joaquin and Ortigalita faults and are shown on the map in Figure 42. The largest nearby quake was the Coalinga Quake with a magnitude of 6.7 in 1983, located approximately 36 miles south of the Mendota site (page 53). The nearest to the Mendota site were three small quakes (<3.0 magnitude) between ~2.5 to ~5 miles away; the most recent of these occurred in 1998 (Figure 43). The application states that the relative risk of the proposed site is low compared with the active zones associated with major faulting (page 53). In order to more fully assess seismic risk at the Mendota site, more information will be needed about local stresses and fracture networks (page 54).

Questions/Requests for CES:

- *The application, on page 53 states, that the "relative risk of the proposed site is low compared with the active zones associated with major faulting." Please clarify how the seismic risk profile for the site will be quantified, particularly in the context of a seismically active region.*

Objectives for Pre-Operational Testing:

- *Incorporate geomechanical information (dipole sonic logs), formation microimager (FMI) logs, and micro-seismic monitoring into the analysis of seismic risk to inform setting of operating conditions and emergency response planning.*

Facies Changes in the Injection or Confining Zones

The facies descriptions and depositional history as described in the permit application are consistent with the presence of interbedded shales and submarine fan deposits, including a lenticular shape for the sandstone units.

The description of the lithology from the B.B. Co 1 well is at a depth corresponding to the Fourth Panoche Sand. Figure 5 in the application narrative, however, shows the Second Panoche Sand as the primary injection formation, with the Fourth Panoche Sand as an optional formation. Given the latter, and the vertical heterogeneity inherent in a shallow marine environment with turbidites and shallow marine shale facies, the lithologic characteristics of these two sands and the surrounding shales at the Mendota site will need to be confirmed during the pre-operational testing program. This would help identify any facies changes that could provide potential preferential flow paths (i.e., high permeability zones) or otherwise affect containment and fluid movement.

CES has indicated that 3D seismic profiling and a characterization well will help in assessing the extents, thicknesses, and lithologies of the injection and confining zones.

Objectives for Pre-Operational Testing:

- *Characterize the geologic units, including the geometry, thicknesses, and extents of the sand and shale units and confirm that these are consistent with current understanding of the depositional history and facies changes expected at the Mendota site based on the 3D seismic survey.*
- *Determine if there are any heterogeneities within the Second Panoche Sands that could affect its suitability for injection, including facies changes that could facilitate preferential flow.*
- *Collect seismic, core, and well logging data that will support characterization of subsurface heterogeneity and refinement of a refined geomodel.*

Structure of the Injection and Confining Zones

The Panoche Formation and the Moreno Shale formations were deposited at the same time as the Great Valley deposits in the east and pinch out against basement rock to the east as shown in Figure 3 and Figure 4 (Bartow, 1990) (Scheirer, 2003). It is difficult to confirm the pinch out as a sealing factor from Figure 4 (page 16). CES states that models of depth, thickness, and areal extent of the injection and confining zones were created using well and 2D seismic data that were incorporated into a geomodel in Petrel (page 33). Future cross sections should show an areal view with transects labeled.

The current information on the general geometry of Fault 13 is shown in Figure 22. There are, however, uncertainties regarding its characteristics (e.g., displacement, sealing capabilities). CES plans to clarify the fault's location and characteristics.

CO_2 plume simulations show the plume migrating up-dip to the northeast, away from Fault 13 (page 27). The regional dip of this and other formations is noted as being about 4 degrees to the southwest (page 18; Figures 16 and 17). On page 71, however, the text states that "…The regional dip of this [the Panoche] and other formations is to the northeast; this implies that the injected CO_2 will migrate approximately 2 miles to the northeast (Section 3)." The text on page 71 may be in error as it is inconsistent with other sections of the text and with the figures and cross sections.

Questions/Requests for CES:

- *Please clarify if the text on page 71 regarding the dip to the NE is in error as it is inconsistent with discussion in other sections and with several figures.*
- *What are the primary mechanisms for lateral confinement? Is it based solely on sand pinch out? If so, please provide evidence to confirm the pinch out as a sealing factor (as this is not entirely clear in Figure 4).*
- *To what degree are the faults expected to affect lateral confinement?*

Objectives for Pre-Operational Testing:

- *Verify fault locations and sealing properties based on the results of the 3D seismic survey.*
- *Confirm the lateral thickness and homogeneity of injection targets.*

CO_2 Stream Compatibility with Subsurface Fluids and Minerals

Section 2.8.4 (page 65) and 2.8.5 (page 66) describe the geochemical model setup and reaction path simulations that were performed to assess interactions between the injectate and the formation solids and fluids. Modeling was done using the geochemical modeling program Geochemist's workbench.

CES notes that the simulations show a net reduction of rock mass and volume. This would result in increased porosity and (potentially) permeability.

CES should update the initial geochemical modeling effort when new data on fluid chemistry and mineralogy are available from the formation testing. Potential effects of water-rock interactions on porosity and permeability may require more refined modeling and will not be fully known until the operational phase of the project.

Questions/Requests for CES:

- *Will the autoclave testing mentioned in the application or any other laboratory experiments be conducted to help refine the modeling?*
- *Will surface area (BET) measurements be done to refine the modeling?*

Objectives for Pre-Operational Testing:

- *Generate fluid chemistry and mineralogic data, pressure, temperature, and pH conditions at depth via core sampling and formation testing in the characterization and monitoring wells to provide inputs to the geochemical modeling.*

Confining Zone Integrity

The integrity of the upper confining zone (Moreno Shale) is based on the thickness and continuity of the unit from seismic and other information, the presence and properties of faults and fractures, and information on petrophysical and lithologic characteristics from available core and well log data. According to the isochore maps in Figure 13, the Moreno Shale ranges from 800-1,650 feet thick in the proposed AoR (page 40). This will be confirmed during testing.

The current porosity and permeability estimates for the Moreno Shale are 8% porosity and 4.7 mD for permeability (Table 3). The porosity appears low and the permeability appears somewhat high for a shale. These need to be confirmed with site-specific data collected during pre-operational testing. Other parameters relevant to confining zone integrity include the capillary entry pressure, which was estimated using the Van Genuchten model because of the absence of laboratory measurement (page 50). CES notes that other tests to assess confinement zone integrity include formation microimage log measurements and drill stem testing (DST) or Modular Dynamics Tester (MDT) stress testing (page 50).

Objectives for Pre-Operational Testing:

- *Confirm mineralogy, porosity, permeability, capillary entry pressure, and geomechanical properties of the Moreno Shale based on core sampling and laboratory measurements to confirm that the Moreno Shale will retain its integrity at planned operating conditions (i.e., injection pressures).*
- *Obtain well log data from all shale units that can provide containment to allow log-based estimates of VCL, porosity, permeability, and TDS.*
- *Test for changes in capillary entry pressure due to reaction of the shale with the injectate via laboratory experiments.*
- *Determine the fracture pressure of the Moreno Shale via a step-rate test.*